The effect on wave nonlinearity on monopile and tower. Fatigue loads in misaligned wind/sea conditions

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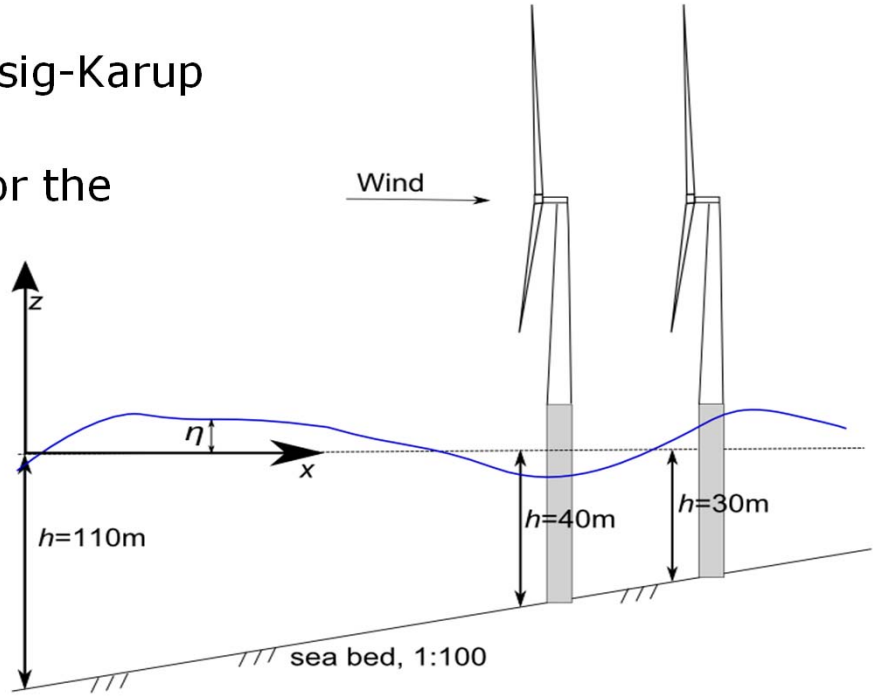
The models

- Fully nonlinear wave model [Engsig-Karup et.al. (2009)]
  - Solve the Laplace equation for the velocity potential
- Aeroelastic code
  - Flex5 [Øye, S. (1996)]
  - Nrel 5MW wind turbine on a monopile

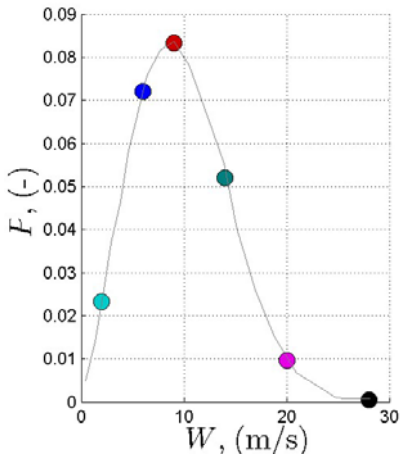


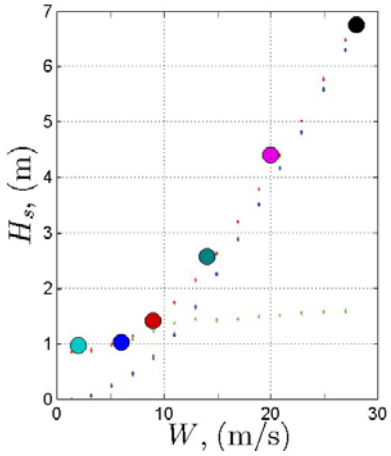
Posible to comare fully nonlinear and linear irregular waves

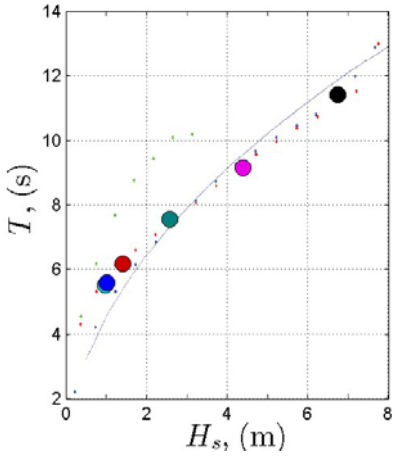
Metocean data

From the North Sea

V (m/s)	H_s (m)	T_p (s)	$P_{rel,j}$	$P_{rel,i,j} \cdot 10^2$						
				0^o	30^o	60^o	90^o	120^o	150^o	180^o
2	0.99	5.50	0.1	1.0	2.2	1.8	1.5	1.2	1.2	0.59
6	0.99	5.50	0.3	6.6	10	5.7	3.2	2.0	1.7	0.74
9	1.41	6.17	0.35	11	14.2	5.2	2.0	1.1	0.67	0.29
14	2.57	7.56	0.22	9.1	9.6	1.9	0.53	0.22	0.14	0.11
20	4.40	9.16	0.04	2.0	1.7	0.19	0.013	0.015	0.010	0.0
28	6.75	11.41	0.002	0.12	0.076	0.007	0.0	0.002	0.0	0.0



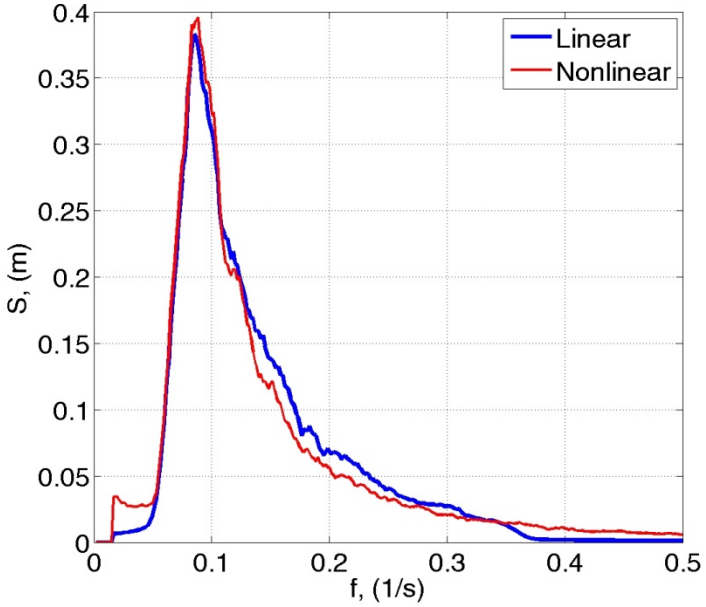




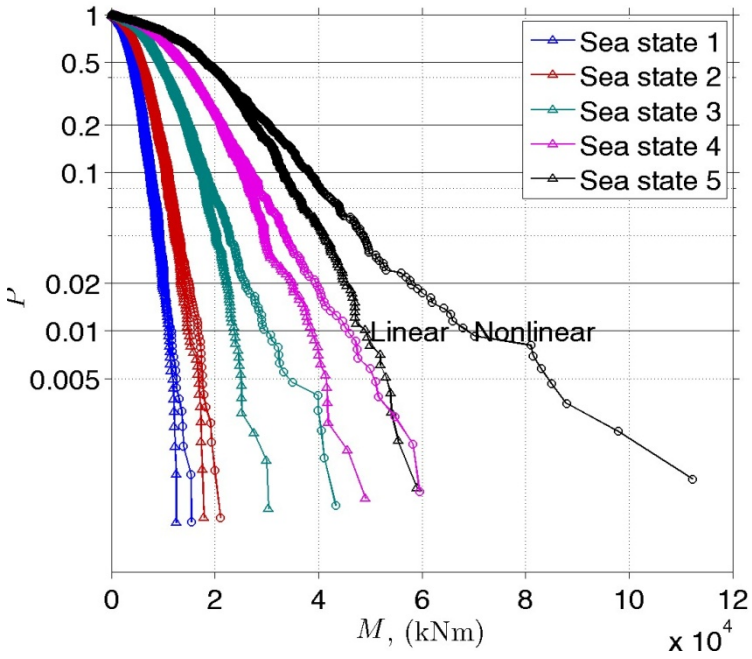
Linear and nonlinear wave realizations

Spectrum and overturning moment

h=30 m, H_s=6.75m, T_p=11.41s



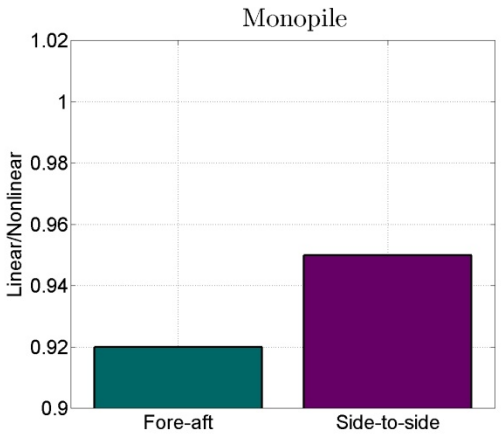
h=30 m

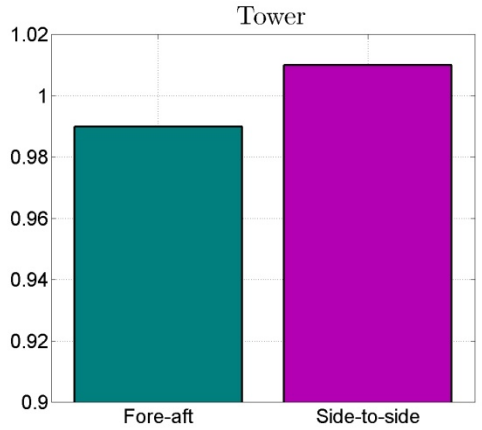


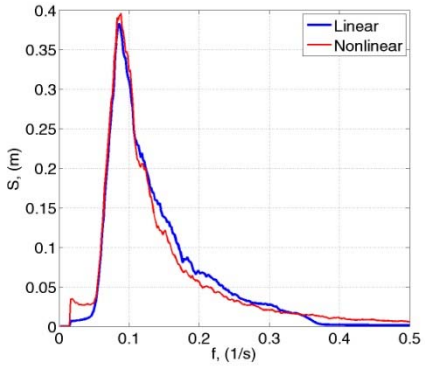
Accumulated fatigue damage

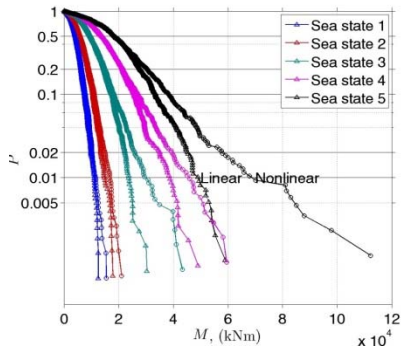
Overturning moment, $m=5$, $h=40$m

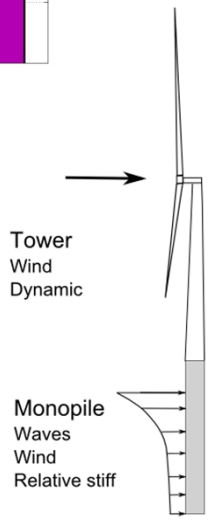
Misalignment wind and waves











Accumulated fatigue damage

Effect of water depth
Alignment wind and waves